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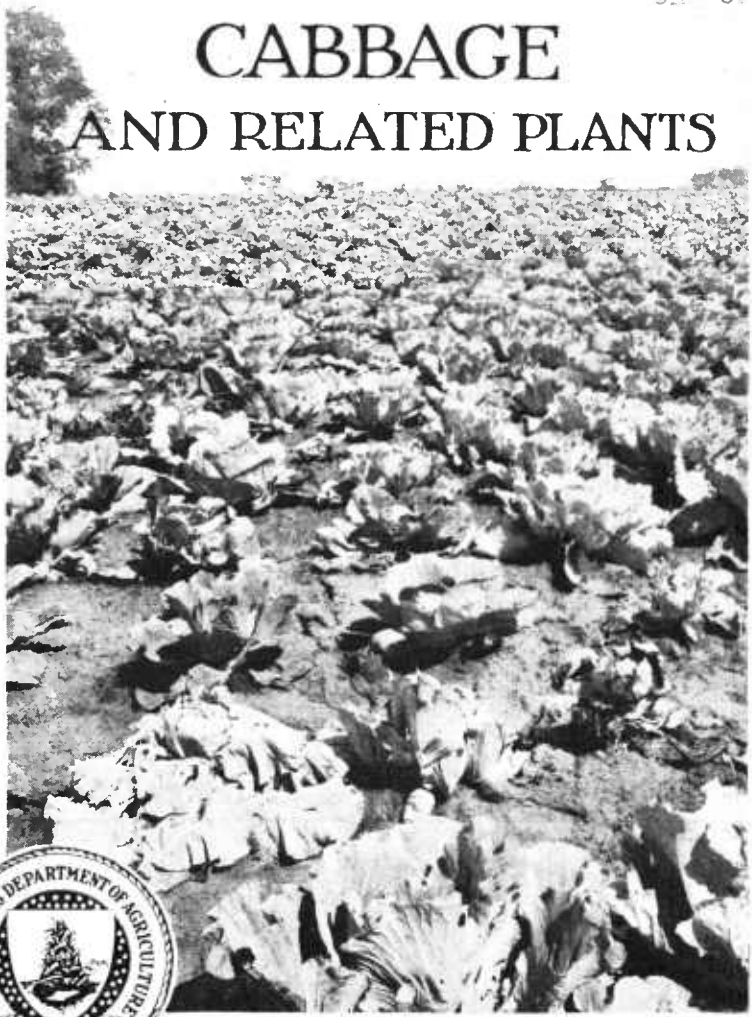
DISEASES OF CABBAGE AND RELATED PLANTS



CABBAGE DISEASES are preventable in the main by simple means of plant sanitation.

Rotation of crops should be practiced, avoiding crops which belong to the cabbage family, such as cauliflower, turnips, Brussels sprouts, and kale. Keep down mustard and related weeds which har bor cabbage pests.

Drainage water and refuse from diseased cabbage fields will carry infection. So will stable manure with which diseased material has been mingled.

The seed bed is often the source of infection. The greatest pains should be taken to insure healthy plants. Locate the seed bed on new ground, if possible, or sterilize by steam the soil used.

Clubroot is avoided by the free use of lime and by setting healthy plants. Disinfect all cabbage seed before planting, to prevent black rot and blackleg. Yellows is due to a fungus which persists in the soil for many years. Varieties of cabbage resistant to this disease are available.

This bulletin is a revision of and supersedes Farmers' Bulletins 925 and 1351.

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DISEASES OF CABBAGE AND RELATED PLANTS

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CABBAGE AND OTHER CRUCIFERS

FROM the original wild stocks of the cabbage group have come our cultivated cabbage, cauliflower, broccoli, Brussels sprouts, kohl-rabi, collards, and kale. Other cultivated plants closely related to those already mentioned are turnip, radish, rape, rutabaga, and charlock. Among the related wild plants shepherd's-purse, peppergrass, and mustard are of most frequent occurrence. Mustard is sometimes cultivated, but it grows so profusely under all conditions that it is perhaps better classed as an obnoxious weed. The term "crucifers" used in this bulletin refers collectively to all the vegetables and weeds mentioned in this paragraph, which belong to the botanical family Cruciferae, so called from the form of the 4-petaled flower. Many of them are subject to the same diseases, so that the methods of control of the diseases of cabbage can often be applied to other crucifers as well.

IDENTIFICATION OF DISEASES

It is the purpose of this bulletin to describe the outstanding symptoms of each disease, to discuss the nature of the causal agency, and to point out such remedial measures as are known. The various diseases can, to a large extent, be identified by the outward appearance of the affected plants. In certain cases, however, points of

similarity often lead to confusion. In order to aid the reader in diagnosis, the following key is given:

Descriptive key to cabbage diseases

HOW THE VARIOUS DISEASES ARE DISSEMINATED

Fungous and bacterial diseases are carried from one place to another by various means, such as (1) insects, (2) infected seed, (3) transplanting from an infected seed bed to the field, (4) surface drainage water, (5) cabbage refuse and stable manure, (6) farm animals and tools, and (7) wind.

INSECTS AS DISEASE CARRIERS

Insects frequently are distributors of disease. For instance, the bacteria causing the black rot of cabbage are carried from one plant to another and from one leaf to another by slugs, snails, etc. Insect wounds offer favorable places for infection with certain diseases. Insects which visit cabbage and other crucifers are likely to carry

the germs on their bodies and deposit them on the parts of noninfected plants. If the conditions are favorable, infection then takes place.

Certain insects are attracted to diseased areas of plants by the odors emitted therefrom. Cabbage affected with clubroot has a very offensive odor at some stages in the development of the disease, and this odor has been known to attract insects. The insects, burrowing through the ground or feeding upon the roots, carry the disease from the roots of one plant to those of another.

INFECTED SEED

Cabbage growers seldom raise their own seed, but usually receive it through the customary seed trade channels located in different sections of the United States or even in foreign countries. The germs of several of the most serious cabbage diseases, including black rot and blackleg, are commonly carried with the seed. For this reason it is of fundamental importance that the source of seed be known and that precautions be taken to lessen the danger from seed-borne diseases. As to the source of seed, the evidence indicates that the Puget Sound district is relatively free from blackleg and black rot, and there is ground for hope that owing primarily to climatic factors it may remain so permanently. In any case it is always advisable as a precautionary measure to treat the seed with some disinfectant before sowing (see pp. 5–6), unless it is known with certainty to be free from seed-borne disease germs.

TRANSPLANTING

Plants that are started in a crowded seed bed, which is often located on old cabbage ground near the house or in the garden, are frequent carriers of diseases to a noninfected field. In such crowded conditions diseases are readily communicated from one plant to another. The loss in the field can be greatly reduced if care is used to prevent the introduction of disease into the seed bed, by proper disinfection of the seed and selection of clean soil or by soil disinfection where rotation is impracticable.

SURFACE DRAINAGE WATER

Drainage water or the run-off during heavy rains probably furnishes one of the most important means for the dissemination of plant diseases and has been found in many places to explain the presence of a disease in fields where cabbage or other crucifers have never before been grown. If the crop is planted on high ground the germs from the refuse of diseased plants may be washed to the low-lying fields during heavy rains. In the hope of avoiding disease by crop rotation a new field on this low ground may be selected where the disease will prove as severe as on the abandoned field.

In some sections where cabbage is grown on a commercial scale it is customary to set the plants with a machine which drops about a half pint of water for each plant. For this purpose the water from drainage ditches, which is often the run-off from a field where some bad disease has been present, being the most available, is frequently

used. This use furnishes another method of spreading disease, as was illustrated in a field set to cabbage for the first time, where the water used in setting a part of the field was obtained from a well; for the remainder, water from a drainage ditch adjacent to a field planted to cabbage the previous year was used. The plants set in both portions of the field were obtained from the same seed bed. The yellows was very severe where the plants were set with water from the drainage ditch; the other part of the field was free from it.

CABBAGE REFUSE AND STABLE MANURE

A not uncommon practice is to throw the refuse of cabbage or other crops on the manure heap, the compost thus formed being hauled out and distributed on the fields the following spring. Near sauerkraut factories the refuse is often spread directly on the cabbage land and plowed under. These are bad practices if the crop is diseased, as the causal organisms may thereby be readily disseminated.

The value of cabbage leaves as fertilizer is doubtful. They contain nearly 90 per cent of water, so that even if all the dry matter had fertilizing value, the quantity is ordinarily so small as to be of minor importance. In any case the refuse should be plowed under on fields designed for the culture of crops other than cabbage or its relatives.

The stems and chaff from even mildly infected seed plants may serve as a source of disease. One case has been noted where surface drainage water carried the blackleg fungus from a pile of such refuse of the previous season to a near-by plant bed, resulting in a general infection. Such material should be burned or disposed of in some other proper manner.

DISTRIBUTION BY FARM ANIMALS AND TOOLS

Although the use of sheep or other animals in cabbage fields is recommended for saving the waste, it should be remembered that the worst diseases are perpetuated in the stem and root tissues, which are not eaten. On the other hand, grazing animals passing from the cabbage lands to other fields may scatter the germs of cabbage diseases. Many of these germs pass through the digestive tract unharmed, and in any case they are easily carried with the soil on the feet of animals. Reasonable care, therefore, should be exercised so that infected soil will not be transported to new cabbage fields by cultivators, other tools, or draft horses. While such practices are in some degree unavoidable in farm operations, these dangers should always be understood and all reasonable precautions taken to avoid them, especially with such serious soil-borne diseases as clubroot and yellows.

DISSEMINATION BY WIND

Dissemination by wind is perhaps not so important a factor in the distribution of diseases of cruciferous plants as some already mentioned. Nevertheless, in certain districts where the soil is light, where dry weather prevails a part of the year and high winds are common, spores may be carried long distances. The diseases that

are external to the leaves are more likely to be distributed in this way than parasites which are situated in the soil or in the internal portion of the plant.

FARM PRACTICE IN RELATION TO DISEASE CONTROL

Several methods by which diseases may be carried from one plant to another, from one field to another, or, indeed, from one part of the country to another, have already been pointed out. In view of these facts, the first aim of the farmer should be to prevent, if possible, the introduction and distribution of destructive diseases on his farm. In order to accomplish this several precautions should be observed, of which the more important are the disinfection of seed or the production of disease-free seed, the location and care of the seed bed, and crop rotation.

DISINFECTION OF SEED

American cabbage growers, as a rule, prefer to buy seed rather than grow their own, and in general this custom is based on sound economic principles and is likely to continue. Seed growing is an industry in itself, requiring specialized cultural methods and certain favorable climatic conditions. Because of these facts most of the American supply of cabbage seed is grown on Long Island or near Puget Sound or is imported. Persons engaged in the seed-growing industry, as a rule, are not well informed about most cabbage diseases and use no special precautions to insure the production of seed free from the germs of disease. Certain diseases, including black rot and blackleg, develop on seed plants and are disseminated with the seed, and probably nearly all the other disease parasites discussed in this bulletin may do so under some conditions. It is therefore probable that disease germs are very commonly being distributed with the seed. Unfortunately there is no sure means of determining by examination, microscopical or otherwise, whether or not a certain lot of seed is free from infectious germs, except by growing plants from the seed under conditions favorable for disease development. The cabbage grower may guard against much of this danger by the disinfection of his seed before sowing. The process is simple and safe and is applicable to cauliflower, turnip, and other crucifers, as well as to cabbage.

Procure corrosive sublimate (mercuric chloride) in tablet form at any drug store, and, following the directions on the package, make up a 1 to 1,000 solution in water. Place the seed in a sack of a thinly woven material, such as coarse cheesecloth, having it large enough to allow thorough agitation of the seed. Soak for 30 minutes and follow by a thorough rinsing in clean water. Then split the sack and spread out the seed in a thin layer to dry, stirring as needed. Since **corrosive sublimate is a deadly poison,** care must be taken to keep the solution out of reach of children and farm animals.

This treatment is sufficient to kill germs adhering to the exterior of the seeds. It is therefore an almost perfect measure against seed-borne black-rot germs (see p. 16), but in the case of blackleg (see p. 21) the germ invades the seed coat to a certain extent. In this case the seed treatment is not entirely effective, and with frequent

rains a few infected seeds may be sufficient for a considerable spread of the disease throughout the seed bed. This fact makes it the more important that greater attention be paid by seed retailers, growers, and growers' organizations to the condition of the crop from which their supply comes, as to its freedom from seed-borne diseases. The control of these diseases by their elimination at the seed source is the more desirable because of the lack of complete disinfection for blackleg with the use of mercuric-chloride solution. The establishment of more definite cooperation between seed growers, seed dealers, and cabbage growers in regard to the question of disease-free seed would lead to a reduction in losses from black rot and especially blackleg.

PRODUCTION OF DISEASE-FREE SEED

Blackleg and black rot are more or less prevalent in all of the cabbage sections in the Central, Eastern, and Southern States. With both maladies the germs are readily carried over winter on even mildly infected seed heads, and they then attack the seed plants the following season. From a diseased field it is almost impossible to select with certainty seed heads which are free from these diseases. The most effective means of ridding seed stock from the diseases, therefore, is to start with clean or thoroughly disinfected seed. If such seed is infected with blackleg, the germ may be almost completely eradicated by soaking the seed for 30 minutes in water held constantly at 122° F. This treatment will reduce the percentage of germination somewhat and can therefore be recommended only for special cases and not for general use. By combining clean seed with a clean seed bed (see the next paragraph) and a clean field, these troublesome diseases may be avoided and clean seed produced. The cabbage seed-growing section of Puget Sound appears so far to be free from blackleg. A study of climatic conditions as affecting this disease leads to the belief that the dry season there in midsummer serves to prevent its development in that region. If further observations substantiate previous findings, the control of blackleg may be solved by the consideration of this fact in purchasing seeds or arranging for contract growing.[1]

LOCATION AND CARE OF THE SEED BED

Cabbage, cauliflower, and some other plants of the same family are generally started in a seed bed before being set in the field. As previously pointed out, some of the worst diseases of these crops may be transferred to noninfected fields by means of the plants from the seed bed. In order to grow strong, vigorous plants as quickly as possible, compost or stable manure is applied liberally to the seed bed. The mistake is often made of placing the bed on an old cabbage field where diseases may have been present, because the soil happens to be fertile or for other reasons. Furthermore, the manure might be, and often is, taken from the heap where diseased plants have been thrown to compost, or it may be from animals that have fed on diseased cabbage. In either case there would be great danger of intro-

[1] For further details as to seed treatment and the production of disease-free seed the reader is referred to the following: WALKER, J. C. SEED TREATMENT AND RAINFALL IN RELATION TO THE CONTROL OF CABBAGE BLACK-LEG. U. S. Dept. Agr. Bul. 1029, 27 p., illus. 1922. This bulletin is obtainable from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 10 cents.

ducing the diseases into the seed bed. The transfer of such plants to the field would naturally mean the transfer of the diseases affecting them. To avoid this danger the seed bed should always be made on new soils if possible. Where it is necessary to use old soil which may contain germs, it should be disinfected.

W. W. Gilbert, of the Bureau of Plant Industry, recommends the following methods for disinfecting the seed beds by sterilization: (1) By means of draintile laid in the bottom of the beds, through which steam is passed; (2) by means of an inverted pan under which steam is admitted; or (3) by drenching the soil with a formalin solution.

In the tile method of steaming, lines of 2-inch to 3-inch glazed tile are placed lengthwise in the beds to be sterilized, 2 to 2½ feet apart and 15 inches below the surface, and are left there permanently. They provide drainage for the beds, may be used for subirrigation, and are available at any time for sterilizing the soil, the only outlay for labor being the covering of the beds with boards or a tarpaulin and the connecting of the tile with a boiler by means of a piece of steam hose. The soil need not be moved, and thus a large part of the labor involved in sterilization is obviated. It is advisable, however, to spade up the soil, so that the steam may more readily penetrate it.

Another method of steaming, by means of an inverted galvanized-iron or wooden pan 6 feet wide, 10 feet long, and 6 inches deep, under which steam is admitted, has been used in the sterilization of tobacco seed beds and in greenhouse beds and has given very satisfactory results. The use of steam at a pressure of 80 to 100 pounds and treatment for half an hour to an hour after the soil has reached a temperature of 212° F., as indicated by soil thermometers, has given the best results. Detailed directions for soil sterilization by the method here outlined will be found in Farmers' Bulletin 996.[2]

Formaldehyde sterilization is accomplished by drenching the soil with a 1 to 100 or 1 to 200 solution of standard formaldehyde (40 per cent), at the rate of three-fourths of a gallon per square foot of area, several days before the soil is to be used. Formaldehyde, however, does not rid the soil of nematodes, as steaming does. This method has been used to good advantage in the sterilization of lettuce beds for the prevention of fungous diseases.

DANGER IN USE OF CABBAGE PLANTS FROM ANOTHER LOCALITY

In this connection it is necessary to warn against an inherent danger from the increasing traffic in cabbage-seed plants. Although it is often the case that one may purchase plants brought from a considerable distance with apparent advantage as compared with the use of home-grown seedlings, nevertheless this practice is always fraught with danger. Numerous cases have been observed where the loss from black rot or blackleg on crops grown from such seedlings was much greater than with home-grown stock planted alongside. Disease infection in such seedlings may occur without being evident upon ordinary inspection, and such diseases as clubroot, root knot, and yellows once introduced may thereafter persist indefinitely.

[2] BEINHART, E. G. STEAM STERILIZATION OF SEED BEDS FOR TOBACCO AND OTHER CROPS, U. S. Dept. Agr. Farmers' Bull. 996, 15 p., illus. 1918.

CROP ROTATION

Because of the fact that the germs of certain cabbage diseases overwinter in soil and refuse, repeated cropping of the soil with the same plant favors the multiplication of the disease organisms. The lack of data as to just how long a time is needed to starve out a given organism, as well as regional variation in climate and soil, makes definite recommendation as to length of rotation beside the point. Blackleg and black rot organisms overwinter in the soil in the North to some extent, but a two to three year rotation of the main field seems to be satisfactory. In the case of yellows, the organism once established is so persistent that its reduction by means of rotation is out of the question. Clubroot is also very persistent in the soil, and long rotation with complete subjection of related wild plants which may harbor the organism is necessary. Even with the less persistent organisms, such as those of blackleg and black rot, fairly long rotation of the seed bed is essential. This is the more important because a small quantity of the organism in the seed bed may spread more rapidly and more widely than in the field, thus causing much greater damage than a similar quantity in the main field.

DISEASES OF CABBAGE AND OTHER CRUCIFEROUS PLANTS

CLUBROOT

Clubroot has been known for more than a century in Europe, where it is widespread in its occurrence not only upon cabbage, but upon other cruciferous crops. It is also known in other parts of the globe, such as Australia and New Zealand. It is widespread in the United States. As a rule it is most troublesome in the market gardening sections around large cities, but in recent years it has become of increasing significance in many larger cabbage-growing regions. The disease affects a large number of wild and cultivated crucifers.

CHARACTERISTICS OF CLUBROOT

The outstanding symptom of the disease is the abnormal enlargement of the roots (Fig. 1). These enlargements may occur on the very small roots, the secondary roots, the taproot, or the underground portion of the stem. As a rule they are thickest at the center, tapering toward either end. The normal processes of the roots are of course disturbed by this malformation. Moreover, the enlargements are protected less against secondary soil organisms, so that decay of the root galls commonly occurs before the end of the season.

The effect of this root disturbance is eventually to stunt the plant. This does not always occur promptly, however. A seed bed, for instance, may show no evidence of disease in the above-ground parts of the plants, but when the plants are pulled they are found to have fair-sized root galls. Likewise, infection occurring in the main field may easily escape notice because the stunting of the plants is often very slow and gradual. Mildly affected plants may form fair-sized heads. If the environmental conditions favor rapid development of the disease the stunting may be sudden and pronounced, and wilting of the plants during the middle of bright days may occur. Permanent wilting may accompany advanced decay of the enlarged roots.

CAUSE OF CLUBROOT

The direct cause of clubroot is a minute organism, one of the slime molds,[3] the spores of which remain in the soil for long periods of time. With favorable temperature and moisture, some of the spores germinate and each gives rise to a small motile body which penetrates the underground parts of the cabbage plant. Once within the host it enlarges, probably divides, and progresses slowly through the tissue. The presence of the parasite stimulates abnormal growth of the affected parts, resulting in the galls. Later the organism divides into innumerable individual spores which are so constituted as to be able to withstand long periods of unfavorable weather. They are returned to the soil upon the rotting of the cabbage roots.

CONTROL OF CLUBROOT

Liming the soil is the most specific remedial measure for clubroot. Air-slaked lime is more effective than ground limestone. It should be applied shortly before planting and in sufficient quantity to neutralize the soil, if acid in reaction, and to leave an excess of lime.

It has been shown experimentally that infection takes place more readily in a moist than in a moderately dry soil. Moreover, clubroot is found oftener in low, poorly drained spots in the field than in the higher parts. Good soil drainage therefore is important and where necessary should be combined with the liming.

FIG. 1.—Enlarged roots of cabbage caused by the clubroot organism

Seedlings are very susceptible to the disease, and the utmost precaution must be taken to grow the plants on uninfected soil, or disinfection of the seed bed should be practiced. Furthermore, diseased plants where practicable should be destroyed and not thrown on the manure pile or left in the field. Crop rotation should be practiced; and, as it has been found that the disease will live in the soil for several years, the rotation should be a long one. All cruciferous weeds should be destroyed, and no cultivated crucifers should be used in the rotation.

ROOT KNOT (CAUSED BY NEMATODES)

In trying to distinguish between root knot and clubroot some confusion is likely to result. Although the organisms causing the

[3] *Plasmodiophora brassicae* Wor.

two diseases are quite different, the effects produced on the roots bear some points of resemblance. (Compare figs. 1 and 2.) Root knot is generally characterized by smaller swellings than clubroot, and infection as a rule is more uniformly distributed on the lateral feeding roots. If upon breaking open the swellings on the roots pearly white bodies about the size of a pinhead are found, root knot is to be suspected. These white specks within the swelling are the enlarged egg-bearing female nematodes or eelworms, which cause the disease. The interior mass of clubroot is slightly pinkish or brick colored. Root knot affects a great variety of unrelated plants, while clubroot, so far as known, occurs only on crucifers.

FIG. 2.—Enlarged roots of cabbage (root knot) caused by nematodes

Furthermore, root knot is confined largely to the light, sandy soils in the South, although it may occur in the Northern States.

CONTROL OF ROOT KNOT

Crop rotation has been found to be the most practicable means of controlling this disease, the object being to use crops immune or resistant to root knot for the purpose of starving out the eelworms. When this method of controlling disease is employed, a rotation of at least three years, accompanied by clean cultivation to keep down weeds, should be practiced. There are more than 500 different species of plants already known to be susceptible to root knot, among which are many cultivated plants and numerous weeds.

The following lists of the more important immune or highly resistant crops and of the crops and weeds known to be susceptible to root knot and therefore to be avoided on infested fields will be of assistance in planning rotations for the reduction of the trouble.

Crops largely or entirely immune to root knot

Barley.
Bean, soy (Laredo variety only).
Bean, velvet.
Beggarweed, Florida.
Chufas.
Corn.

Cowpea, Brabham.
Cowpea, Iron.
Cowpea, Monetta.
Cowpea, Victor.
Grass, Bermuda.
Grass, crab.
Grasses (nearly all).
Kafir.
Millets (nearly all).
Milo.
Oats, winter.
Peanut.
Rye.
Sorghum.
Wheat.

Crops susceptible to root knot

Alfalfa.
Asparagus.
Bean, Lima.
Bean, snap.
Bean, soy (all varieties except Laredo)
Beet.
Cabbage.
Cane, sugar.
Carrot.
Celery.
Clover, bur.
Clover, sweet.
Collard.
Cotton.
Cowpea (all varieties except Iron, Brabham, Monetta, and Victor).
Cucumber.
Eggplant.
Fig.
Lettuce.
Muskmelon (cantaloupe).
Okra.
Pea, garden.
Peach.
Potato.
Potato, sweet.
Radish.
Salsify.
Spinach.
Squash.
Strawberry.
Tobacco.
Tomato.
Vetch, common.
Watermelon.

Weeds attacked by root knot

Balloon vine.
Clover, Mexican.
Fennel, sweet.
Maypop (passion flower).
Papaya (melon papaw).
Mayweed.
Purslane.

On fields badly infested with root knot, only immune or highly resistant crops should be grown, especially if this field is to be used in future years for growing cabbage or other crucifer crops.

If the disease occurs in the seed bed or greenhouse, the soil should be sterilized by live steam in accordance with one of the methods referred to on page 7.

YELLOWS

Cabbage yellows occurs seriously from Long Island to Colorado, including the southern parts of New York, Michigan, Wisconsin, and Minnesota, and southward as far as cabbages are grown as a summer crop. It is worse in warm, dry summers, and does little or no damage in the cooler extreme northern sections or along the northern Pacific coast. The winter-grown cabbage of the Southern States usually escapes the disease. In certain intensive cabbage-growing sections in the region first indicated, especially in the latitude of New Jersey and Maryland westward to southern Wisconsin, Iowa, and Kansas, this disease has been rapidly increasing in extent and seriousness. In bad seasons it may destroy 90 per cent of the crop in individual fields and, indeed, is the limiting factor in success with cabbage as a field crop. The disease may also be destructive to kale, collard, and kohl-rabi. Cauliflower, broccoli, and Brussels sprouts are in the main highly resistant.

CHARACTERISTICS OF YELLOWS

Plants infected with the yellows usually show the characteristic symptoms in two to four weeks after transplanting, but the disease may appear in the seed bed. The first sign is the lifeless, yellowish green color of the foliage. Sometimes the yellowing is uniform; more often it is worse on one side, causing a lateral warping or curling of the stem and the leaves. (Fig. 3.) Early symptoms of the disease can be seen by cutting across the base of the stem, where the invaded vessels of the woody ring show a darker water-soaked color than healthy ones. This color deepens to a dark brown with the progress of the disease, but not to a deep black as in the case of black rot. (See p. 16.) The overlying tissues gradually die and collapse, resulting in a discolored sunken surface and the curving or warping of the stem already mentioned. The yellowed plants early shed their lower leaves while making a weak attempt to continue growth above. In the worst case death may result within two weeks or so after transplanting, but most of the plants continue a sickly existence for a month or more, and a few live through the summer, heading imperfectly. (Fig. 4.) In these later stages when the interior browning is most pronounced it may be difficult to distinguish yellows from black rot; therefore the two diseases are often confused.

FIG. 3.—Cabbage yellows. A seedling plant dwarfed and leaves curled by one-sided infection. A normal plant of this age should be twice as large

CAUSE OF YELLOWS

Cabbage yellows is caused by a soil fungus.[4] This organism once introduced seems capable of persisting indefinitely in favorable soils even though cabbage is not grown. The parasite requires high temperatures, and even on the "sickest" soils it does not attack the cabbage until the soil warms up to about 60° F. or above, which in the Northern States means midsummer. This explains the varia-

[4] *Fusarium conglutinans* Wollenw.

tions in the seasonal and geographical distribution of the disease—cool, moist summers tending to lessen the loss and hot, dry seasons to aggravate it. Infection takes place through the roots and is especially injurious immediately following transplanting, when the new root system is being developed. The fungus develops rapidly within the stem and leaves, which are killed and discolored as it progresses from the roots upward. From thus crippling or destroying the absorbing and conducting systems of the plant, gradual starvation results.

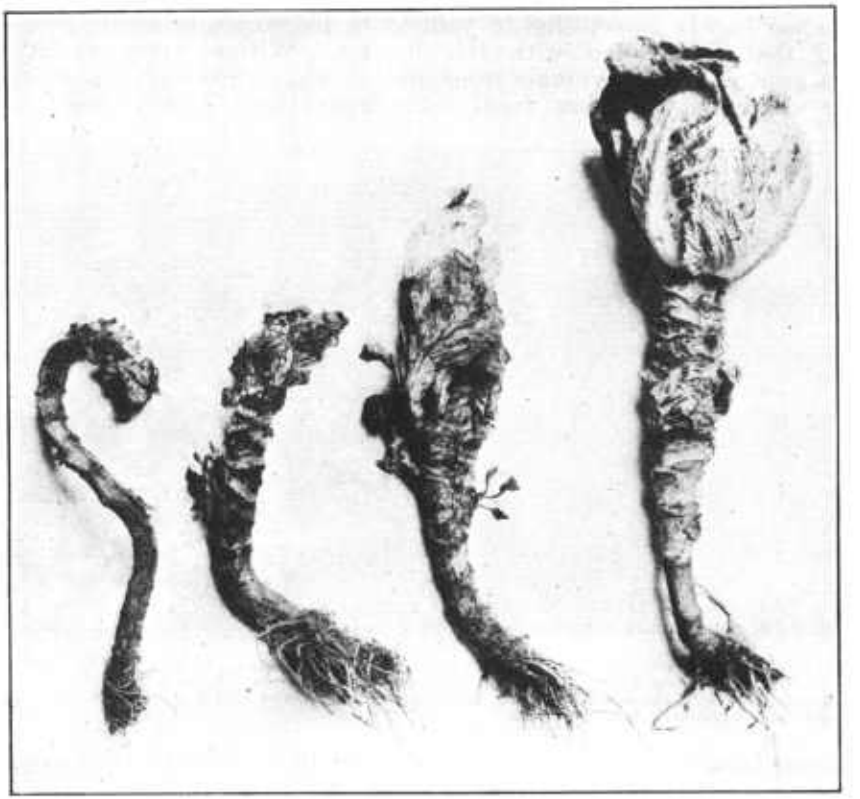

FIG. 4.—Cabbage yellows, later stages. Where the plants are not attacked too severely or are somewhat resistant they may continue a sickly existence through the season. Such plants are yellowish and the lower leaves keep dying and falling. The attack is often worse on one side, warping or curling the stems

CONTROL OF YELLOWS

The yellows parasite, if once introduced, persists indefinitely in the soil. Sanitary measures and crop rotation are recommended, but these alone do not suffice to control yellows. Seed-bed infection is one of the worst dangers; hence, great care should be taken to plant the seed in clean soil. Steam sterilization of seed-bed soil may be practiced to advantage by market gardeners, but of course for extensive field operations this can not be done. Even if perfectly healthy plants are transplanted into an infested field they may be

attacked badly. The only safety, therefore, lies either in planting the crop on disease-free land or else in using only yellows-resistant varieties, as listed below. In infested districts especial precautions are necessary to check the spread of yellows to new soil. Farm tools, animals, and surface water are common carriers, and a case is recorded where the disease was introduced by using infected drainage water when setting the plants.

YELLOWS-RESISTANT VARIETIES

All of the older varieties of cabbage in general use in this country are too highly susceptible to yellows to be grown successfully on soil that is infected with this disease. Within every variety, however, a few individuals resist the disease. (See figs. 5 and 6.) By continued selection from such individuals, highly resistant

FIG. 5.—Cabbage yellows. Commercial Hollander, a nonresistant variety (on the left), showing only a few sickly plants still alive among the weeds. Wisconsin Hollander, a resistant variety (in the rest of the field), giving practically a full stand, although the soil was uniformly "yellows sick"

strains have been obtained which will produce a normal crop upon badly diseased soil.

Cabbage growers wishing seed of resistant strains will find them listed for sale by a number of seedsmen. If they are unable to procure them through this channel, they should write directly to the agricultural experiment station in the State in which they reside.

A number of yellows-resistant varieties which are now in general use are listed below. Still others are in process of selection and will be introduced as soon as practicable.

Wisconsin Hollander No. 8.—A selection from Hollander or Danish Ballhead. The variety is somewhat coarser and a heavier yielder than the average strain of the original type. It matures a week to 10 days later than some strains of Danish Ballhead. It is used for late shipping and storage purposes.

Wisconsin Hollander No. 9.—A selection from the above. It is slightly earlier and finer than No. 8. Both strains were developed in southeastern Wisconsin by the Wisconsin Agricultural Experiment Station and are now in general use in that and other sections.

Bugner's.—A selection made from a late storage variety by Mr. Bugner, a gardener near Chicago, Ill. It is very similar to Wisconsin Hollander No. 8 and is highly resistant. It is used extensively in the vicinity of Chicago.

Wisconsin All Seasons.—Developed by the Wisconsin station from All Seasons, which it resembles in type, except that it matures a little later. It is a drumhead variety and is used widely for sauerkraut manufacture in yellows-infested areas.

Wisconsin Brunswick.—Selected from Brunswick at the Wisconsin station. It is a drumhead variety, maturing about the same time as Wisconsin All Seasons. It is used for sauerkraut manufacture though not so widely as the latter.

Maryland Flat Dutch.—Selected from Flat Dutch at the Maryland Agricultural Experiment Station and further improved at the Wisconsin station. It is an extremely late-maturing strain and is not very uniform. Probably for these reasons it has not come into general use.

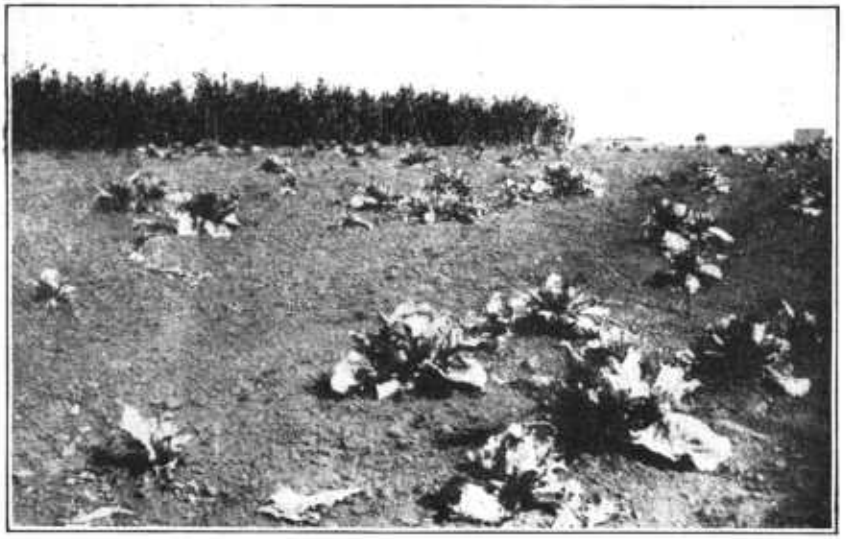

FIG. 6.—A field with "cabbage-sick" soil, most of the plants having been killed by the yellows. A few plants have withstood the disease, and if such are selected for seed and the process repeated for several years a resistant strain may be obtained. (See fig. 5)

Goepper's.—A variety developed by Mr. Goepper, a gardener near Indianapolis, Ind. It is a selection from Louisville Drumhead and is very resistant to yellows. It is used to some extent in the vicinity of Indianapolis.

All Head Select.—A flathead type selected from All Head Early. It is a midseason variety and matures about 10 days earlier than Wisconsin All Seasons. It has been developed through the cooperation of the Wisconsin station, the United States Department of Agriculture, and the National Kraut Packers' Association. The first distribution of seed of this variety in any large quantity is that of the 1926 seed crop for 1927 planting.

Marion Market.—A midseason roundhead variety selected from Copenhagen Market under the same auspices as All Head Select. It matures in about the same season as the latter and is thus somewhat later than the earliest strains of Copenhagen Market. Seed of this variety is available for 1927 planting.

Globe.—A midseason roundhead variety selected from Glory of Enkhuizen under the same auspices as All Head Select. It matures in about the same season as the latter and Marion Market. A very limited quantity of seed is available for 1927 planting.

Iacope.—A selection from Copenhagen Market, made at the Iowa Agricultural Experiment Station.

Red Hollander.—A late roundhead variety of red cabbage developed by W. J. Hansche at Racine, Wis. It is highly resistant and matures in about the same season as Wisconsin Hollander No. 8.

PRODUCTION OF SEED FROM RESISTANT VARIETIES

Many cabbage growers provide themselves with seed by selecting and saving heads for planting out the following spring. This is a commendable practice and insures reliable stock at a low cost where equipment for successful storage of seed heads is available. Care should be taken to select heads of good type from thoroughly diseased soil where the few susceptible individuals have been eliminated. Cabbage is cross-pollinated by bees, and the seed plants should not be grown within 40 rods of any other variety. When growing cabbage seed, one should aim to keep the stock free from blackleg and black rot. If the seed plants become infected with either of these diseases, the seed should be disinfected before using.

Since the regions where yellows is severe are not best for cabbage-seed growing, the supply of local-grown seed of resistant varieties has not kept pace with the rapidly increasing demands. This has led to the sending of stock seed from yellows sections to one or another of the commercial cabbage seed-producing centers for multiplication. This practice, though commendable, is fraught with some dangers which will inevitably lead to disappointment unless certain precautions are taken. It should be remembered that the yellows-resistant strains are not absolutely immune, and a small percentage of susceptible weaklings always occurs. In the commercial cabbage-seed sections, where yellows is not a factor, these weaklings are not eliminated by the disease. There may be expected then a gradual reversion to the susceptible type where constant propagation is practiced on healthy soil. Experience, however, has led the writer to believe that there is no marked reversion if only one crop is grown on healthy soil, provided one returns each time to stock seed from heads selected on sick soil. For those who individually or collectively wish to follow this practice the following precautions are recommended:

Produce the stock seed from typical heads selected out of plantings of the resistant variety on "yellows-sick" soil.

Test this stock seed on a sick soil alongside a susceptible variety the following season.

If the stock seed is satisfactorily resistant, it may be used for multiplication in a cabbage seed-growing locality, provided it is completely isolated so as to avoid cross-pollination.

Test the increase crop of seed on sick soil before releasing for general use.

BLACK ROT

Black rot is quite as widespread in its occurrence as clubroot, and very few cabbage regions in the United States have escaped it. Since it is very often started from diseased seed, and the parasite does not remain indefinitely in the soil as do the clubroot and yellows organisms, it is more spasmodic in its appearance in the Northern States. It appears to be more generally prevalent in the South, where the organism persists more easily because of the milder climate. A number of wild and cultivated crucifers are susceptible to this disease.

CHARACTERISTICS OF BLACK ROT

The plant may be affected at any stage in its growth. The disease is confined almost entirely to the above ground parts of cabbage. Infection takes place primarily through water pores at the margin of the leaf. The progress of the disease from this point can frequently be traced through the veins of the leaf (fig. 7, c) by the blackening of the bundles. The marginal infection is later followed by a browning and drying up of the infected areas of the leaf. Invasion also commonly occurs through wounds made on the leaf by biting insects. The organism progresses down the leaf to the main stem, where it may advance up or down. As it goes up the stem younger leaves are invaded. The affected bundles in leaf or stem are always easily recognized, upon cross sectioning, by their blackened appearance. If plants are infected while still young, dwarfing or one-sided growth commonly occurs. In extreme cases heading is prevented. Black rot does not cause a soft rot of affected heads, but it opens the way for soft-rot bacteria (see soft rot, p. 27); consequently soft-rot symptoms are common in association with black rot. For this reason it is dangerous to store heads from fields where black rot occurs.

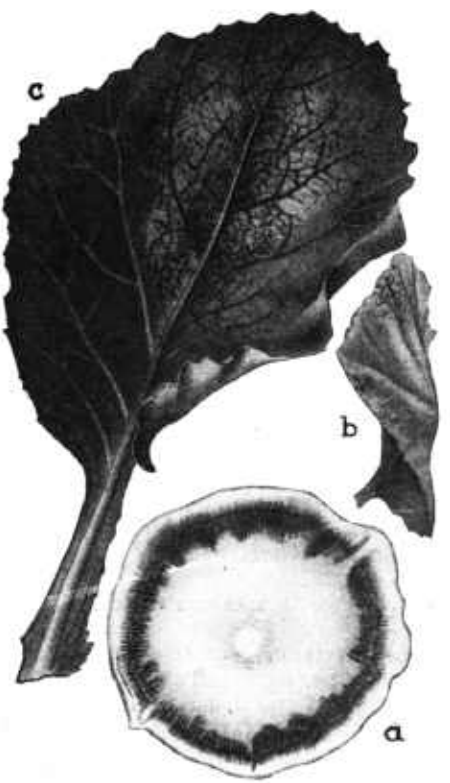

FIG. 7.—Black rot. *a*, Section through a cabbage stem, showing the conspicuous ring of black bundles caused by the black-rot organism; *b*, infection through the veins at the margin of a leaf; *c*, a cabbage leaf, showing the blackening of the veins as a result of the invasion of the black-rot organism

There are some points of resemblance between yellows and black rot which often lead to confusion. This is occasioned by the fact that both cause discoloration of the bundles and both may bring on one-sided development of the leaves or of the whole plant. In the main the bundles affected by black rot are black and in the later stages they are commonly surrounded by cavities due to breakdown of surrounding cells. With yellows the bundles are brown and no cavities occur.

CAUSE OF BLACK ROT

Black rot is caused by one of the bacteria.[5] These minute organisms are carried about by insects, spattering rain, surface drainage water, and possibly by wind, or with wind-borne particles of dust.

[5] *Bacterium campestre* (Pammel) EFS.

They are able to swim about in liquid, and when they come in contact with drops of liquid which collect on the margins of leaves or about insect wounds they enter the water pores or wounded tissue. They are able to penetrate the tissue until they reach the conducting vessels, and from then on they multiply in and progress chiefly through this channel. They may be carried over from year to year in old cabbage tissue, possibly in the soil, and on or within the seed.

CONTROL OF BLACK ROT

Since the causal organism may live in the soil or on seed and may be transmitted by insects, the following precautions should be observed to hold the disease in check:

(1) Seed should be disinfected before sowing, in accordance with the method described on page 5.

(2) Care should be exercised in the preparation of the seed bed, and only manure and soil that are known to be free from the organism should be used.

(3) Crop rotation, whether for the prevention of disease or not, is always a good practice. In connection with the black rot it is very important, since the germs are known to survive the winters of even our northern States. To control the disease by this method the rotation should be one in which no cultivated crucifers or cruciferous weeds are allowed to grow in the ground for two or three years.

(4) Insects, slugs, snails, etc., by crawling from infected to noninfected plants, carry black-rot organisms. When possible they should be kept in subjection.

(5) Livestock should not be allowed to roam at will over diseased cabbage patches, as they may carry the organisms to noninfested fields.

MALNUTRITION, A NONPARASITIC DISEASE

Malnutrition is a trouble which affects cabbage, cauliflower, and other crops, especially in the Southern States. It is quite different from any of the diseases previously discussed, all of which are caused by parasites. Malnutrition may be caused in several ways, such as by the excessive use of mineral fertilizers, the lack of humus, or the accumulation of acids in the soil.

CHARACTERISTICS OF MALNUTRITION

The most characteristic symptom of malnutrition is a change from the normal green of the leaves to a light green or yellow between the veins and around the margins. (Fig. 8.) The lower leaves are the first to show symptoms; then the upper and inner ones. All diseased leaves are perceptibly thickened and so brittle as to be easily crushed between the fingers.

The heads from plants slightly affected are small and immature; when plants are badly diseased no heads are formed.

The roots are small and the lateral feeders few in number and frequently dead at the end. Often the epidermis of the stem at the surface of the soil is injured, the injury closely resembling that caused by the corrosive action of some acids and alkalis.

CAUSE OF MALNUTRITION

Malnutrition is often caused by the following conditions:

Constant, clean cultivation for many years has robbed the soil of most of its original fertility. The farmers therefore naturally turned to the use of commercial fertilizers as a substitute. At the outset better crops were obtained than were possible on the best soils without fertilizers. This led the farmers to believe that fertilizers alone were necessary and the more used the greater the yield. When the returns decreased as a result of this practice the quantity applied was gradually increased until it was not uncommon to add as much as 3,000 pounds of mineral fertilizers per acre for a single crop of cabbage. A large part of the fertilizer applied was not used by the plants, but remained in the soil, where in the course of a number of years a considerable quantity accumulated.

Some fertilizers eventually cause what is popularly known as "sour soil." On the other hand, a small quantity of acid in the soil is not generally injurious; but it is not uncommon to find soil in the South so acid as to require 5,000 to 9,000 or more pounds of lime per acre to neutralize it. No agricultural plants will give their best yield under such conditions.

FIG. 8.—A section of a cabbage leaf showing the characteristic symptoms of malnutrition. Between the veins the tissue is a light yellow

CONTROL OF MALNUTRITION

In controlling malnutrition three points need consideration: (1) The adjustment of the composition of the fertilizer to meet the crop requirements; (2) the rational use of lime; and (3) the maintenance of the organic matter of the soil.

The composition of the fertilizer or the ratio of the different substances composing it should be such as to give an alkaline rather than an acid reaction, for acid soils have been found to increase and alkaline soils to decrease the severity of the malady. As malnutrition is worst on acid soils, air-slaked lime at the rate of 1,000 to 2,000 pounds per acre should be added. Humus can be supplied to such a soil by the use of stable manure or by growing green-manure crops, such as cowpeas, soy beans, vetches, etc., to be turned under when mature. The results from this method of restoring natural fertility to the soil are ordinarily very marked on the first succeeding crop.

TIPBURN

Tipburn of cabbage may be caused by several agencies. Extreme drought sometimes brings on more or less burning at the leaf margins, but this is not of very common occurrence. The most acute cases of tipburn are the result of unbalanced nutrients in the soil. It occurs most commonly in the Northern States in recently reclaimed marsh or muck soils. Ordinarily such soils are deficient in potash and phosphorus and comparatively high in nitrogen.

The disease is characterized by yellowing of the leaves beginning at the margins and progressing downward. Usually the entire margin of the leaf and several leaves of the plant show the symptoms simultaneously. The yellowed tissue dries out and becomes brittle, while secondary organisms commonly attack the dead tissue. This condition usually appears about the time the plant starts to head, and in extreme cases the plants do not form hard heads.

This type of tipburn can be readily prevented by application of potash and phosphate fertilizer. Heavy application of stable manure is also effective.

WIRE STEM OR DAMPING OFF

Wire stem is often encountered as a damping-off disease of seedlings in the seed bed. It is of widespread occurrence in the United States.

The malady may appear when the seedlings are 1 or 2 inches high. The stem becomes water-soaked at the surface of the soil and the plant may topple over and die. Very often the plants show black sunken lesions which may completely girdle the base of the stem and decidedly weaken it. Plants which are growing rapidly and are very succulent are the most susceptible. Plants seem to become more resistant as the stem becomes more woody. Very commonly the seedlings outgrow the disease. Such individuals have in the region of the soil a tough, woody stem which is brownish or black in color.

Wire stem is caused by a fungus [6] which is widely distributed in many soils. It attacks a large number of plants, including potato, but it is possible that various strains of the organism exist which may be restricted to certain host plants. It appears that the form which commonly attacks potato does not attack cabbage, whereas the cabbage form does not infect potato. The disease seems to progress at any soil moisture or temperature which is favorable for the growth of the plant. It is probable that certain other fungi may cause damping off of cabbage seedlings, but very little study has been made of them and they appear to be less generally prevalent than wire stem.

Sanitation and rotation of the seed bed are essential in the control of wire stem. The disease may be further checked by applying to the soil immediately around the plants a stream of corrosive sublimate solution, 1 to 2,000 (one-half the strength recommended for seed treatment). Apply 4 to 6 days after the plants are up, and repeat at intervals of a week for 4 to 6 weeks.

This treatment is also effective against the cabbage maggot and should be used in any case where that insect is troublesome.

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[6] *Corticium vagum* B. and C.

BLACKLEG

Blackleg occurs very generally in the regions where cabbage has been grown for long periods in most States east of the Rocky Mountains. With the exception of two or three instances of minor importance, it has not been reported from the Pacific coast regions. The loss is ordinarily small if proper precautions are taken as to sanitation, seed bed, and rotation. Where these are disregarded the loss may range from 5 to 10 per cent up to 50 to 100 per cent of the crop. (Fig. 9.)

CHARACTERISTICS OF BLACKLEG

The disease is known to be destructive only to cabbage and cauliflower, but the causal fungus has been shown to be able to attack

FIG. 9.—Blackleg of cabbage, causing the wilting and dying of the lower leaves and a loss of over 75 per cent of the crop in a field

Brussels sprouts, kohl-rabi, collards, rape, kale, rutabaga, turnip, radish, sweet alyssum, and variously related cultivated and weed plants of the mustard family. It may invade almost any part of the plant, but the worst damage occurs when it blackens and kills the stems of plants in the seed bed or field; whence its common name.

The earliest symptoms may appear in the seed bed two or three weeks before transplanting time. Infection frequently occurs on the stem near the surface of the ground, causing dark sunken or irregular areas. From these spots the disease spreads, gradually killing the base of the stem and root (fig. 10), so that the plant wilts and perishes. Such wilting of the entire plant is characteristic of the advanced stages of blackleg, and the leaves adhere to the stem (see fig. 9) instead of falling off as in yellows. Frequently plants attacked by blackleg show a purpling of the leaves as the first conspicuous

symptom, even before any wilting occurs. Often the disease may appear as dead spots on the older leaves or leafstalks, and with seed plants the spotting of the flowering branches and seed pods (fig. 10) is common. It is often difficult to distinguish the stem rot caused by blackleg from maggot injury, the more so as the two often occur together. It is also sometimes confused with the wire stem. (See p. 20.) Certain other fungi also cause leaf spots resembling those of blackleg. (See p. 24.) It is important, therefore, to note that

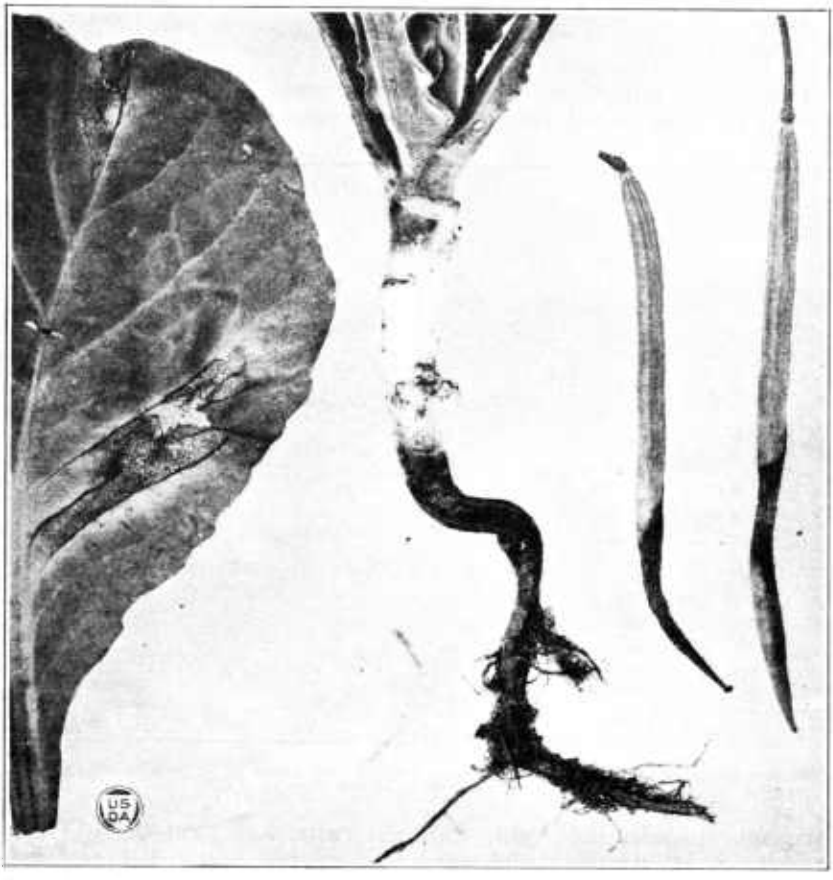

FIG. 10.—Blackleg of cabbage, showing injury and blackening of the main root and diseased spots on the leaf and seed pods, in which numerous small black fruiting bodies of the causal organism are evident

the peculiar character of blackleg which serves to distinguish it is that in its advanced stage the dead areas are covered with minute raised black specks, like pin points. (Fig. 10.) These are the fruiting bodies (pycnidia) of the parasite, filled with the spores by which the disease is disseminated.

Even this symptom may be confused with that of ring spot (see p. 24), which also has pycnidia in the dead areas on the leaf. In the case of ring spot the fruiting bodies are much smaller, more numerous, and more closely crowded together.

CAUSE OF BLACKLEG

Blackleg is caused by a parasitic fungus.[7] This may be carried with the seed and persists in the soil. The first infections commonly take place in the seed bed, more often in the stems than on the leaves. Maggot or other insect injuries presumably favor infection, although infection occurs readily in the absence of wounds. The rate of development varies widely with temperature and moisture, but under favorable conditions the parasite kills and discolors spots on stems or leaves, and within two weeks these are usually thickly studded with numerous black specks about the size of a pin point. (Fig. 10.)

In these black bodies are contained the spores, which are small and colorless and upon oozing out are distributed primarily by water to healthy leaves and new plants. Wet weather is most favorable to the rapid spread of the disease, while the occurrence of maggots or flooding with water increases its destructiveness.

CONTROL OF BLACKLEG

The blackleg parasite is harbored in the soil by these spore-producing bodies on fragments of the diseased stems and leaves, which may persist two or more years until the old stumps are fully decayed. It is common in seed fields, especially in the Eastern and Central States, and has been reported in Europe. Where it so occurs the seed may carry the infection. The most serious trouble arises from seed-bed infection, either from the use of infected seed or from making the bed on infested soil. The first precaution, therefore, lies in clean seed and seed disinfection (p. 5); the second, in the selection of clean soil for the seed bed. If old soil must be used, it should be steam sterilized where practicable (p. 7).

Inasmuch as the fungus, once established in the seed bed, is spread from plant to plant largely by spattering drops of water, care should be exercised to avoid unnecessary splashing where artificial watering of the seed bed is customary.

The corrosive-sublimate treatment does not completely rid cabbage seed of the blackleg fungus, but greatly reduces it. Where complete eradication of the organism is desired, even at the expense of some reduction in percentage of germinable seeds, hot-water treatment at 122° F. for 30 minutes, without presoaking, is recommended. A preliminary trial with a few hundred seeds should be made in this case, followed by a germination test, since different seed lots vary as to the extent of their injury from this stronger treatment. For further details as to seed treatment and rainfall in relation to the control of blackleg, the reader is referred to Department Bulletin 1029.[8]

Crop rotation should be practiced, and in general sanitary measures are to be recommended. These involve such precautions as can reasonably be taken to destroy or keep from scattering diseased materials. The use of cabbage plants from another locality, the history of which is unknown, is not advisable. (See p. 7.) It is the more dangerous because of the fact that such plants may bear young infections still invisible, which develop rapidly after transplanting.

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[7] *Phoma lingam* (Tode) Desm.
[8] See footnote 1, (p. 6).

RING SPOT

Ring spot in America is most prevalent on the Pacific coast, where it affects cauliflower, cabbage (including seed plants), kale, and certain other crucifers. It appears in the early stages as dark-purple spots, which gradually enlarge, often becoming an inch or more in diameter on the leaves. (Fig. 11.) The older spots are dark brown, with light-green borders. In advanced stages minute black specks appear in the dead portions of the spot, resembling very much those described in the case of blackleg. They are to be distinguished from the latter by being much smaller, more numerous, and thus more closely crowded. The disease appears on the stems and pods of the seed plants as small spots or as long purple streaks. The disease is not often very destructive in this country. Its chief damage is to cauliflower, to which it often causes losses in transit.

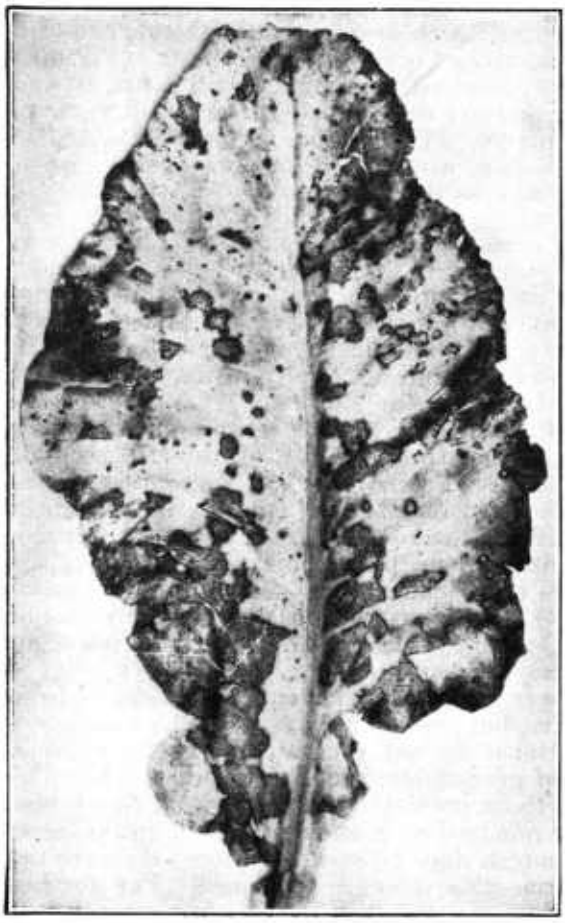

FIG. 11.—A cauliflower leaf attacked by ring spot

Ring spot is due to a fungus[9] similar in appearance and general character to that causing blackleg. It overwinters on seed or on cabbage refuse.

Successful control measures have not been worked out. It is possible that seed disinfection will prove helpful. Where it is a transportation or storage-house problem, as is the case with cauliflower, control must be effected through a change in shipping or storage conditions, in which humidity is held as low as possible and the temperature maintained at 32° F. or slightly above.

BLACK LEAF SPOT (BLACK MOLD, BROWN ROT)

Black leaf spot occurs as a leaf-spot of cabbage, cauliflower, collards, and a number of other crucifers. It also causes black mold of

[9] *Mycosphaerella brassiciola* (Fr.) Lindau.

cabbage heads in storage and a brown rot of cauliflower heads in transit. As a leaf disease it is ordinarily of minor importance, but in storage or transit the organism may be very destructive.

In the field it appears on the lower or outer leaves of the maturing plants as distinct roundish black spots commonly marked with concentric brown zones. (Fig. 12.) These spots vary from one-fourth to one-half an inch or more in diameter. They are distinguished from blackleg spot or ring spot by the absence of the numerous dots (pycnidia) in the diseased area. In storage these spots may blend together on cabbage heads until the outer leaves are covered and entirely blackened by the moldy development. On the curd of cauliflower the disease appears as brown spots which turn olivaceous with age.

The disease is caused by a fungus[10] which lives over on cabbage refuse or with the seed. The "black mold" which develops on the leaf spots or upon cabbage or cauliflower heads consists largely of the dark-colored spores of the organism. These are readily disseminated by wind or water and germinate in water, thus invading healthy plants and causing new infections.

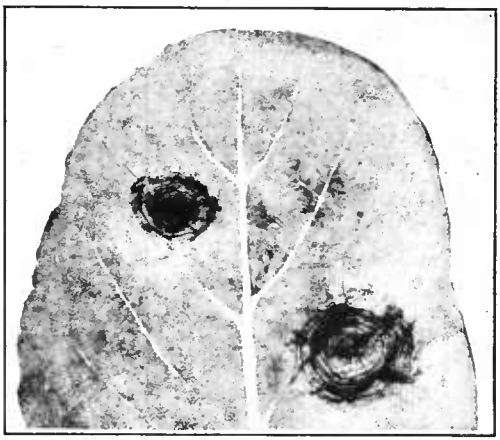

FIG. 12.—Black leaf spot of cabbage; characterized by concentric rings

Black leaf spot ordinarily is not sufficiently important in the field to warrant the practice of specific remedial measures. Seed treatment is hardly advisable in general, because the mercuric-chloride treatment is not effective, and the hot-water treatment recommended for blackleg is necessary to rid the seed from the organism. The disease being most destructive in storage and in transit, care should be taken to handle the crop so as to minimize the trouble. Heads should be handled carefully to avoid bruising and surface moisture allowed to evaporate before storage. The storage house should be kept at 33 to 34° F. and ample ventilation provided to reduce humidity.

SPOT DISEASE OF CAULIFLOWER

The spot disease was first found to attack the leaves of cauliflower, but later was observed on cabbage to a more limited extent. It causes on the lower surface of the leaf, and less abundantly on the upper, small brownish to purplish gray spots (fig. 13) somewhat irregular in outline. A puckering of the leaf results when the midrib and larger veins are badly affected.

[10] The common organism associated with the disease is *Alternaria brassicae* (Berk.) Sacc. Another closely related species may also cause similar symptoms.

During the spring of 1911 some loss was caused to cauliflower in tidewater Virginia, where 25 to 90 per cent of the plants in the worst cases were attacked. It is also commonly prevalent on Long Island.

This disease is due to a bacterium,[11] and no means for its control have been worked out. It has been observed that the spot disease is most severe during cool, damp weather, and is held in check when the warm, sunny days of late spring come on. In view of the fact that the organism is especially sensitive to sunshine and warm weather, it is not likely to cause any serious damage except during protracted rainy, cool weather. Crop rotation should be employed in controlling it.

FIG. 13.—Upper surface of a cauliflower leaf, showing typical injury caused by the spot-disease organism

DOWNY MILDEW

Downy mildew[12] first appears in the seed bed in the spring as a whitish mold in isolated spots on the under sides of the leaves. It may also occur on the stems. At the close of the season the portion of the leaf immediately surrounding the diseased area appears yellow and later turns brown and dries up. Frequently light areas are observed in the center of a dark ring, which in turn is surrounded by a light or yellow area, thus presenting a conspicuous mottled appearance. It seldom causes any serious loss except in seed beds. It has been found in Australia and Europe and has been reported from several States in the United States.

The disease is not often troublesome enough to require remedial measures. Crop rotation should be practiced. The plants should not be grown too thick or kept too wet in the seed bed. If in spite of such precautions the mildew is serious, the plants in the seed bed should be sprayed about once a week with Bordeaux mixture (4–4–50 formula).[13]

POWDERY MILDEW

Powdery mildew is caused by a parasitic fungus[14] which forms a white powdery dust on the leaves of turnips, cabbage, and a few

[11] *Bacterium maculicolum* McC.
[12] Caused by the fungus *Peronospora parasitica* (Pers.) DeBary.
[13] This formula is 4 pounds of copper sulphate (blue vitriol) and 4 pounds of stone lime to 50 gallons of water.
[14] *Erysiphe polygoni* DC.

other plants. The loss caused by this disease is so slight that treatment is unnecessary.

WHITE RUST

White rust may appear as white blisterlike pustules on any aboveground part of the plant, but more frequently attacks the leaves. Distorted and abnormal growths of the affected parts may follow. It is caused by a fungus[15] which occurs commonly on radish and mustards but rarely on the cabbage in America. Since it is common on European cabbage, it seems probable that the parasite as it occurs on cabbage represents a specialized race which as yet has not been widely introduced into America. If so, efforts should be made through destruction of diseased plants to restrict its spread. Precautions to this end should receive special attention if the disease is detected in the seed bed.

SOFT ROT

The loss from soft rot alone or in combination with other rots is considerable both in storage and in transit. It is occasionally destructive in the field, especially following black rot. Freezing injury is commonly followed by soft rot.

FIG. 14.—Soft rot developing on stored head of cabbage

Soft rot of cabbage is characterized by a soft, mushy, almost slimy decay, which after entering, generally at the surface or base of the head, spreads rapidly throughout the whole plant. The soft-rot bacteria as a class are marked by their ability to destroy plants very quickly under favorable temperature and moisture conditions. They seldom affect uninjured plants, but require a wound or other injury to gain a foothold, or they appear in conjunction with the black rot or black-mold troubles. Infection takes place in the field, where considerable damage may be occasioned, but the greatest destruction to this crop is caused in the cabbage storage houses or in transit. Under improper storage conditions the disease spreads rapidly, frequently covering all of the outer leaves, necessitating repeated and excessive trimming. (Fig. 14.) Soft rot is distinguished from other head rots by a characteristic offensive odor given off from the decayed tissue.

Soft rot in cabbage and related crops is due to bacteria belonging to a group usually referred to as the soft-rot bacteria,[16] which may attack carrots, turnips, celery, and other vegetables.

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[15] *Albugo candida* (Pers.) Rous.

[16] *Bacillus carotovorus* Jones is a common example.

It has been found that in storage houses, where the maximum loss occurs, an increase of the temperature much above the freezing point and a high percentage of relative humidity will result in rapid decay. In view of this fact it is advisable that a temperature uniformly 1 or 2 degrees above freezing should be maintained and a comparatively low relative humidity kept by careful ventilation. Furthermore, cabbage and other crops in preparation for storage or shipment should be carefully selected and so handled that they will be injured as little as possible. Since the soft-rot organisms are especially sensitive to light and drying, the crop where practicable should be dried in the sunshine before being put into storage.

DROP (WATERY SOFT ROT)

Cabbage drop is worst in the Gulf coast region, but is occasionally found in northern States. During some seasons the disease causes heavy losses to the crop in southern Alabama and parts of Florida and Texas. Though its distribution has not been thoroughly studied, it is likely that the disease occurs in other States as well. A serious afterresult is that the crop from such fields, when carload shipments are made, continues to develop the disease in transit. This leads to much loss in terminal markets with the symptom known as watery soft rot.

The earliest symptoms of the disease known as drop are indicated by water-soaked areas over the stem and lower leaves. This wilting of the lower leaves is followed by the whole plant collapsing finally into a shapeless mass. The plant may succumb to the disease in a few days, or it may live from one to two or more weeks. In and about the decayed region a dense white cottony mass of mycelium accumulates. In the later stages of the disease irregularly shaped, hard black bodies, the size of a mustard seed or larger, are to be found scattered among this cottony mass. These bodies are almost sure evidence of the disease.

Drop is caused by a fungus[17] which forms a coarse, white growth in and about the decayed region of the plant which it attacks. Later the hard, black bodies mentioned above develop from the mycelium. These serve to carry the fungus during the period of unfavorable environment. In the spring, they send up small mushroomlike bodies which bear microscopic spores in abundance. These are discharged into the air, and when they come in contact with the moist surface of the host plant they germinate and cause infection.

This fungus is best known as the cause of lettuce drop. It also causes a serious disease of the cucumber, carrot, and certain other plants. In view of this fact, care should be taken in the rotation not to follow lettuce with cabbage on fields where drop has occurred. It is further advisable, when possible, to pull up and destroy infected plants. Compost which may contain the refuse of lettuce, cabbage, and other crops that have been destroyed by the fungus should not be used on cabbage beds or in the field. When cabbage is shipped from areas subject to drop it should be sent under refrigeration in order to hold the disease in check.

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[17] *Sclerotinia sclerotiorum* (Lib.) Massee.

RHIZOCTONIA HEAD ROT[18]

The loss from rhizoctonia head rot is occasionally quite serious in the field, though it may also cause damage in storage and in transit. This disease is of widespread occurrence over the central and northern cabbage-growing districts. A short time before harvest, scattered individuals show a dark and firm decay about the bases of the foliage leaves and around the lower portion of the head. The cover leaves of the head soon become dark brown to black and if they are peeled back will show the mycelium of the fungus between the affected leaves. The organism works into the head, producing characteristic dark and sunken spots in the fleshy leaves. Thus many affected heads can not be used for market, but other slightly diseased heads may be brought in from the field and shipped or stored. These decay under average storage conditions and readily spread the disease to adjacent heads. This then produces loss, both from rotted heads in the field and in storage and because of extra labor required for excessive trimming. The rot produced by this organism differs from soft rot in having only a slight odor and attacking healthy uninjured heads in the field. Diseased areas on the plant usually have a few strands of cobwebby mycelium over their surface. The decayed tissue, in the main, has a firmer texture than that of either soft rot or drop.

Rhizoctonia head rot of cabbage is caused by an organism intimately related to the Rhizoctonia which attacks potato[19] but differs in that the cabbage head-rot organism is parasitic only on cabbage. The fungus is most destructive as a head rot in cool weather. It is probably identical with the one which produces wire stem.

Rotation of crops seems to be of little advantage after the disease is established in the soil. Diseased heads should be sorted out and not allowed to come in contact with healthy heads. Cabbage from a diseased field should be handled carefully and if stored kept as near 32° F. and in as dry a condition as possible.

PYTHIUM HEAD ROT

A soft rot of cabbage heads has been described recently, due to still another fungus.[20] It has so far been found only in the markets. The disease travels most rapidly along the midrib, which is reduced to a soft, pulpy consistency and held together by the outer layers of tissue. It is not unlike soft rot in appearance, but microscopic examination shows the presence of mycelium in the decayed tissue, while the characteristic offensive odor of soft rot is absent unless bacteria are present as secondary invaders.

INJURIES FROM WEATHER CONDITIONS

FLOODING

Cabbage is frequently grown on rather heavy flat land which is not well drained. Under these circumstances heavy rains may cause surface flooding, especially in low spots. Where this occurs in mid-

[18] This section was prepared by F. L. Wellman.
[19] *Corticium vagum* B. and C.
[20] *Pythium debaryanum* Hesse.

summer, so that the ground is covered or saturated with water for a few days, especially if followed by hot, sunny days, the fibrous roots are soon drowned or killed from lack of oxygen. Such roots quickly rot, the leaves wilt, and the plants die. It is important, of course, not to confuse the wilting from this cause with similar wilt due to either of the two parasitic diseases already described, clubroot and blackleg.

FREEZING INJURY

Although cabbage will ordinarily withstand light frosts, heavy freezes as a rule are injurious. Plants vary with their stage of maturity in susceptibility to freezes, and when a field is subjected to such condition before harvest very often the partly mature heads recover, while the mature ones are lost. Sometimes the interior of the head is most susceptible and the damage is not noticed until the head is cut open. Frozen tissue is at first water-soaked in appearance and may later turn dark in color. The affected tissue is very subject to decay by soft-rot bacteria, and soft rot commonly affects frozen stock in storage or transit.

LIGHTNING INJURY

The results of lightning injury are occasionally found in cabbage fields. If noted soon after the injury occurs, the plants are found to be most severely affected near the surface of the soil, followed by wilting of the leaves. Eventually the plants in the affected area die, leaving a roughly circular barren spot varying in size with the severity of the electrical discharge.

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